RESEARCH ARTICLE OPEN ACCESS

Economic Return of Using Capacitor Banks in Residential Facilities

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ABSTRACT: This paper proposes the economic return of using capacitor banks in residential facilities. In **Kuwait**, there is a law states that every invested residential building forced to use capacitor bank to improve the power system performance regardless the price of capacitor banks nowadays or the economic status of consumers. So, in this paper, a full research with simulation part will be carriedout to show the effect of using capacitor banks on the economic situation of consumers and the performance of power system. Eventually, some methods will be included to solve the cost problem of using cap. banks.

Date of Submission: 30-03-2019 Date of acceptance: 13-04-2019

I. INTRODUCTION

Capacitor banks have the advantages of reducing high reactance, controlling the voltage level at their end, reducing or eliminating the voltage drop and increasing power transferred.

Fig 1.1 - Capacitor Banks

Capacitor banks are being selected based on some factors:

- The load capability (VAR consumption).
- The voltage level.
- The economic situation.

Basically, capacitor banks can be used to improve the performance of power system by supplying the reactive power required to the consumer and help the grid to supply active power only but there are some factors must be taken into consideration. Capacitors banks have high prices in **Kuwait** which some consumers can't afford. On the other hand, installing capacitor banks to each invested residential building is so difficult, expensive and occupying unwanted space. From the economic and practical aspects, cap. banks approximately cost **4500** KWD or **15000** USD which it's so expensive for the normal consumer. For example, 1250 m^2which is the area of 20 apartments cost a 4500 KWD for a cap. bank, the price is increased with the increasing of building area, and the consumer or the investor has no benefits. Alternatively, other methods can be used instead of using cap. banks such as; using KVAR meter to obtain the KVAR consumption that the consumer would pay or the ministry can use Automatic Power Factor Regulator at the distribution substation to stabilize the voltage and increase the performance instead of using capacitor banks at each invested residential building which will be so expensive. In the following, a comparison of using and not using cap. banks performance on a residential facility, also, comparing the prices will be shown. Eventually, the methods mentioned above will be proposed.

II. PERFORMANCE ANALYSIS AND RESULTS

In the following chapter, the comparisons mentioned in the previous chapter will be carried out using MATLAB/SIMULINK by simulating the residential building and using cap. banks. As a result, the performance of using and not using cap. banks will be shown, also, measuring the KVAR required to the building, calculating its price, and comparing it with the cap. bank price.

2.1 Electrical Load Calculations

Some assumptions and specifications of an invested residential building consists of **12** apartments and every apartment has an area of **120 m^2** will be shown at the next table.

Electrical Appliances	Power (W)	PF
A/C	8000	0.75
Water Heater	1800	0.7
Refrigerator	400	0.72
Washing Machine	1500	0.69
T.V	300	0.8
Dryer	1500	0.75
Microwave	800	0.71
Lighting	1800	0.85
Vacuum	1300	0.7
Oven	1500	0.7
Heater	1500	0.7
2x Elevators	30000	0.8
3x Water pump	4500	0.8

Table 1.2 – Electrical loading of one apartment in addition to the elevators and water pumps.

1.1. Simulation ofthe Residential Building <u>Without</u> Using Cap. Banks

Fig. 1.2 – Simulation schematic for the full building

The total power results from the simulation is:

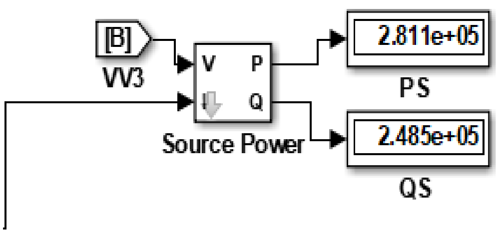

Fig. 2.2 –Power produced from the source.

Then, the total active power of one apartment will be **20400 W** and for all the apartments, the total active power will be **244800 W.**

By assuming that the building has 2x Elevators and 3x Water pumping with efficiency of 100%, regardless the general loads. Then the total active power of the building is:

244800+30000+4500 = 280000 W nearly.

By simulating the loads of the building, the results without adding cap. bank will be as follows:

- **Total Active Power is: <u>281100</u> W.**
- **Total Reactive Power is: <u>248500</u> VAR.**
- **The PF is: <u>0.75</u> nearly.**

As observable, the PF is considered to be low and this will cause some drawbacks on the power system performance such as;

1- The voltage drop in transmission lines will be increased.
2- Poor voltage regulation.
3- Poor power transfer.
4- A large rating transformer will be needed to handle the large current.

2.2 Simulation of the Residential Building <u>With</u> Using Cap. Banks

So, to make on solving this problem, a method of improving PF will be illustrated. Cap. banks will be implemented to improve the PF by reducing the reactive power generated by the source and injecting reactive power to the grid (invested residential building). Let's assume that the desired PF value should be around **0.9** nearly, so, to increase the PF from **0.75** to **0.9**, cap. banks must be attached to the grid. By using the following law we can get the exact power value of added cap. bank that will be used to raise the PF. After obtaining this value of **KVAR**, another simulation will be carried out using cap. banks.

$Q_c = P[\tan\varphi_1 - \tan\varphi_2]$ eqn. (1)

Where:
Q_c: The cap. bank value.
P: Total active power.
φ_1: The old power angle.
φ_2: The new power angle.

So, if the old power angle is **41.41 deg.,** the new power angle should be **25.84 deg.,** and the total active power is **281100 W**, then the power valueof added cap. bank required to improve the PF is nearly **114.4 KVAR.**

Following the simulation of obtaining and adding the cap. bank.

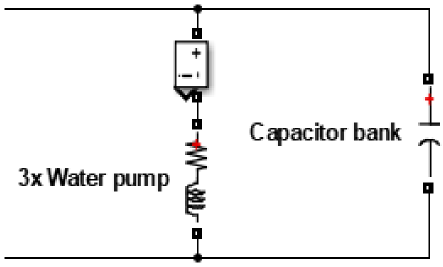

Fig. 3.2 – Adding cap. bank to the simulation

And for obtaining the power value of the added cap. bank.

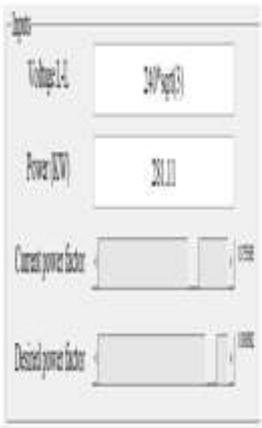

Fig. 4.2 – Inputs of the system

Fig. 5.2 – Results before correction

Fig. 6.2 – Results after correction using cap. bank

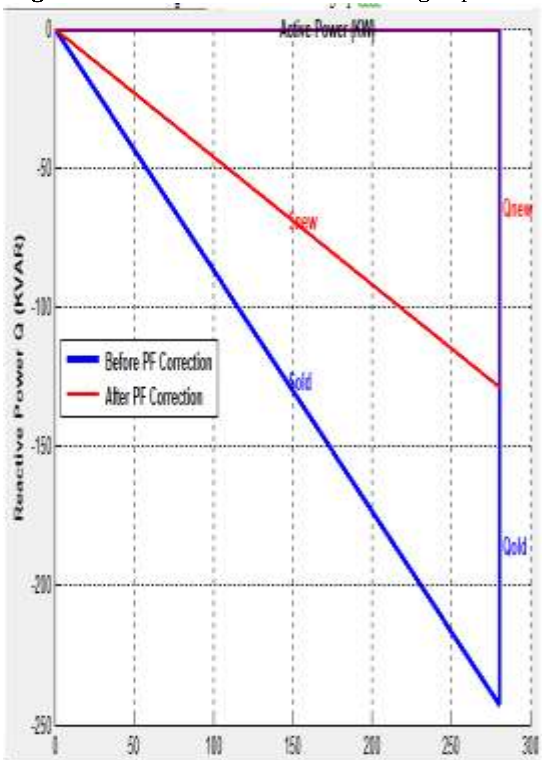

Fig. 7.2 – The graph of power triangle after and before using Power factor correction method.

It's noticed that the reactive power generated by the source is decreased due to using power factor correction (cap. bank). This leads to increase the efficiency and decrease the total loss by decreasing the produced current as shown in Fig. 6.2 and 5.2.

And as illustrated in Fig. 7.2, the power has decreased.

2.3 Reactive Power Meter Method

The previous comparison is considered to be the **MEW** (Ministry of Electricity and Water) point of view to improve the performance and they haven't taken into consideration the consequences of using cap. bank on the normal consumer as the cap. banks have very high price and needed to be installed on large space, also, periodic maintenance is needed. So, there is another method can be used instead of using cap. bank, the ministry can take charge of installing reactive power meter on the invested residential building to measure the consumed reactive power, calculate the PF value and make the normal consumer pay the difference PF value.

From the last comparison, it's observable that the difference reactive power to get the desired PF is **114.4 KVAR,** so, the ministry can ask for paying this difference. By another meaning, if we consider that the annual electricity bill for the invested residential building is **8,500 KWD** and the average PF all over the year is **0.75**, the difference is (**0.9-0.75**) = **0.15**, so, the penalty should be as follows:

0.15*8500 = 1275 KWD.

And this is less and cheaper than installing cap. bank.

2.4 APFR Method

Another method can be used to improve the grid performance which it's called Automatic Power Factor Regulator/Controller. This method considered to be better than using capacitor banks because of the following reasons:

- Capacitor banks need manual operation (On/Off).
- Also, they don't meet the required KVAR under varying loads.
- In addition to, they can cause under voltage, hence, mal-operation of relays.
- On the other hand, APFR causes low energy consumption by reducing loses.
- And eliminate power factor penalty.
- Automatically switch the capacitors (On/Off) to keep the voltage level and PF constant.

For the previous reasons, APFR is the ideal way can be used.
Following the APFR device schematic:

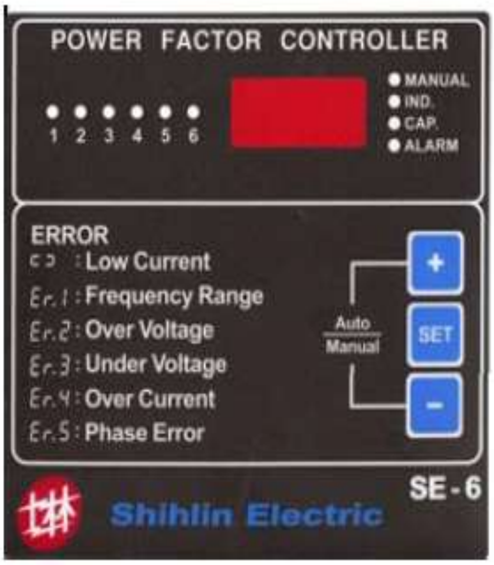

Fig. 8.2 – APFR device

Principle of Operation

There will be a main incoming circuit breaker from main bus which its voltage needs to be maintained constant. APFR device will monitor this voltage.

Also, there will be individual capacitor banks with individual CB of different KVAR based on our requirement.

APFC will monitor the bus voltage and whenever the voltage drops, first cap. bank of some KVAR will be switched on by sending **close** command from APFC. Even after switching on one bank and still voltage is still drops, next bank also will be switched on. This is mostly done using Microcontrollers.

APFR can be located at the Bus Bar related to the distribution substation to make on stabilizing the voltage level and PF at the desired value. From an economic point of view, locating the APFR at the distribution substation is better than putting capacitor bank at every invested residential building, this will save more money instead of spending money on installing capacitor banks everywhere.

Following the Electrical schematic diagram of distribution substation.

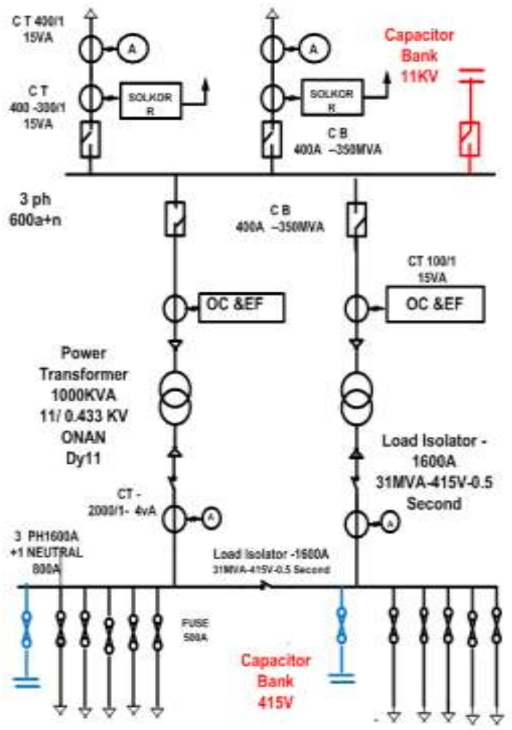

Fig. 9.2 - Electrical schematic diagram of distribution substation

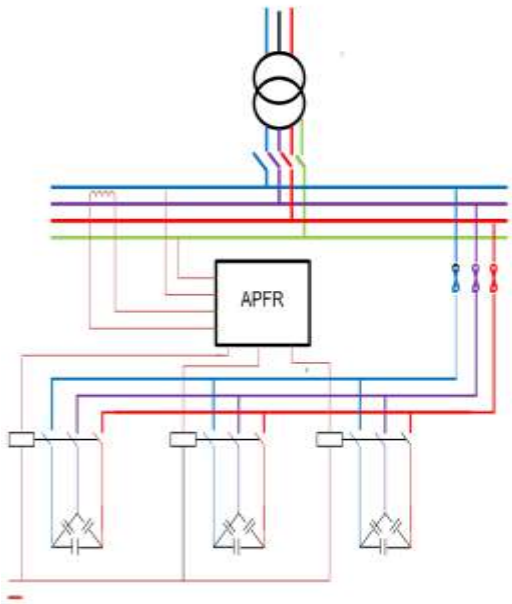

Fig. 10.2 – The precise location of the APFR

III. CONCLUSION

It's concluded from the previous comparisons that installing cap. bank at receiving-end will increase and improve the performance of grid but also, will be more expensive on the normal consumer. So, if a reactive power meter is installed instead of the cap. bank, it will be less cheaper and it will compensate the PF difference by a penalty defined by the ministry. This paper has shown the difference between installing cap. bank, reactive power meter and installing APFR at distribution substation from the point of view of the ministry and also of the normal consumer, and it has taken into consideration the economic return of using cap. bank, using reactive power meter and installing APFR. Eventually, the most convenient method to improve the grid performance and most suitable to the consumer and the **MEW** is using **APFR**. Instead of using fixed capacitor banks for every residential building, APFR can be used at the distribution substation that will feed most invested residential building. Also, installing APFR at distribution sub. Will have less periodic maintenance than using capacitor banks. On the other hand, the ministry can handle more buildings PF Automatically instead of using capacitor bank to control the PF at each.

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Adnan B. S.Alharees " Economic Return of Using Capacitor Banks in Residential Facilities" International Journal of Engineering Research and Applications (IJERA), Vol. 09, No.03, 2019, pp. 55-59